Bull. Environ. Contam. Toxicol. (2000) 64: 122-129

Bulletin of Environmental Contamination and Toxicology

Effects of Anionic Surface Active Agents on the Uptake of Aluminum by *Cyperus alternifolius* L. Exposed to Water Containing High Levels of Aluminum

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Received: 16 April 1999/Accepted: 14 November 1999

The dissolution of Al is one of the main consequences of atmospheric acid deposition in forest soils in large areas of northern and central Europe and North America (David et al. 1984; Mulder et al. 1987) . The increase of ionic concentrations of Al solution has adverse effects on soil. Grusven et al. (1992) observed that the logarithm of Al dissolution rates in individual soil samples followed an inverse linear relationship with pH. Also, together with pH, organic matter, organic chemical substances complexes showing that Al concentration in solution reaches a minimum value in a pH range of about 4-5. Above pH 5, the concentration of Al in solution increases dramatically. It has been clearly observed that Al-organic matter is soluble in the pH range 5-7 (Hargrove 1986). This experimental finding confirms with previous studies regarding Al availability to plants exposed to Al with anionic surface active agents.

Surfactants or surface active agents represent potential toxicants. They have many applications in both domestic and industrial operations. They are found in adhesives, foods and beverages, dyestuffs, fibers. Processes such as electroplating, lubrication, ore flotation, emulsion polymerization and paper manufacturing all represent a significant portion of the uses of synthetic surfactants. Combined worldwide consumption of surfactants (anionic, cationic and non-ionic) was estimated to be 15 million metric tons in 1989 (Berth et al. 1989). The popularity of synthetic detergents raised a particular interest for the effects of surfactants on the growth and metabolism of plants (Muramoto et al. 1984, 1988a, 1988b, 1989) in ground water and wastewater . Removal of the residual surfactants from the effluents (Muramoto et al. 1996) is a very important task, imposing expensive physical and chemical processes. The biodegradation processes carried out naturally in fresh water systems (wastewater, river water) are still very promising for the complete removal of synthetic detergents (Larso 1994).

The worldwide uses of surfactants shows that about 70% are anionic, 50% of which carry a sulfonate or a sulfate hydrophobic head group. The anionic sodium dodecyl sulfate (SDS) is well known for its wide use in the production of shampoos: foam baths, toothpaste and dish washing detergents as well as in many biochemical studies. Therefore, SDS was chosen in this study to test the effects of anionic surfactants on the growth of aquatic organisms responsible for carrying out biodegradation processes in natural waters. Industrial effluents containing nonbiodegradable surfactants still flow into natural waters, causing profound effects on the aquatic environment Lewis et al. 1986; Muramoto et al. 1996). Aquatic plants can assist in wastewater cleaning. However there are few reports for the water cleaning on the metal uptake and surface active agents. *Cyperus alternifolious* L. was used as test

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plants due to its relatively good tolerance to polluted water and to changes in polluted aquatic conditions. This study are examined on the uptake of aluminum and SDS by *Cyperus alterinifolius* L.

MATERIALS AND METHODS

Cyperus alternifolius L. were obtained from Kyusyu University in July in 1997 and were kept in plastic tanks containing tap water with chemical fertilizer about 14 days for acclimation. Adult plants of *Cyperus alterinifolius* L. were kept in 2.0 L glass pot in phytotron house, where they were maintained at 25 ± 2 °C. There were altogether 13 such groups: four kept in aluminum solution ($AlCl_3$ 6H2O) alone at concentrations of 0.1, 1, 10, 100 mg/L: four groups containing 100 mg/L SDS plus the same aluminum concentrations as above: five groups kept in solutions containing only SDS concentrations of 5, 50, 100, 250, 500 mg/L. The aluminum and anionic surface active agents (sodium dodecyl sulfate, SDS) content of the plants was analyzed on the lst, 7th, 14th, and 28th days after the beginning of the exposure experiments. The water of each pot was changed twice a week and was adjusted pH 5.3. Water characteristics (tap water) were (mg/L): Ca 12.0; Mg 1.7; Na 4.1; K 0.9; SO4 5.2; Cl 4.2; SiO_2 12.5; Alkalinity 37.9 as $CaCO_3$; Dissolved solid 64.8; SDS < 0.001; Al 0.005; Cu < 0.005; Zn 0.04; Cd < 0.005. The roots and tops of plants were carefully washed with 0.4M KNO_3 solution for the determination of anionic surface active agents, SDS. Analytical procedures the methods using the flameless atomic absorption spectrophotometer (HITACHI 9000) after application of $CHCl_3$ extraction method with ethylene diamine-copper ion and chloroform at pH 7.0 (Lewis et al. 1986). Also for metal analysis, each plant sample was dried at 60 °C for 48 hours in a hot-air dryer, and was dissolved in HNO_3-$HClO_4$ (2:1) and made up a fixed volume by addition of 1N-HCl. This solution was used for determination of Al using flameless atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Relationship between the concentration of SDS in water and the length of root of *Cyperus alterinifolius* L. at the 28th days from the beginning of the experiments was given in Fig, 1. No effect of SDS on the increasing ratio of root length was indicated within 50 mg/L SDS in water but significant decreases were observed for concentrations of SDS 100 mg/L in water. At the 500 mg/L SDS in water. the growth ratio of root length was decreased approximately to 70 % compared with those of the control. The effect of SDS content in water to the *Cyperus alternifolius* L. is relatively lower than those of water hyacinth .

Figure 2 shows the concentration of Al in root and stem of plant exposed to Al containing water with or without SDS 100 mg/L. The concentration of Al in roots and tops of *Cyperus alterinifolius* L. tended to increase with the exposing time. The uptake of Al in roots was higher than those in tops of plant exposure for 28 days. However, the concentration factor of roots and tops of plants exposed to Al with or without 100 mg/L SDS was not decreased compared with those in Al alone group. The concentration factors of plant in metal alone group is slightly higher than those in metal with SDS group on the contrary other metals, such as cadmium and nickel with SDS (Muramoto et al. 1989). The content (microgram of dry matter) of the Al in roots and tops of *Cyperus alternifolius* L. exposed to Al containing water with or without SDS 100 mg/L for 28 days are presented in Fig.2. and the significant differences were recognized between the root and tops of the plant.

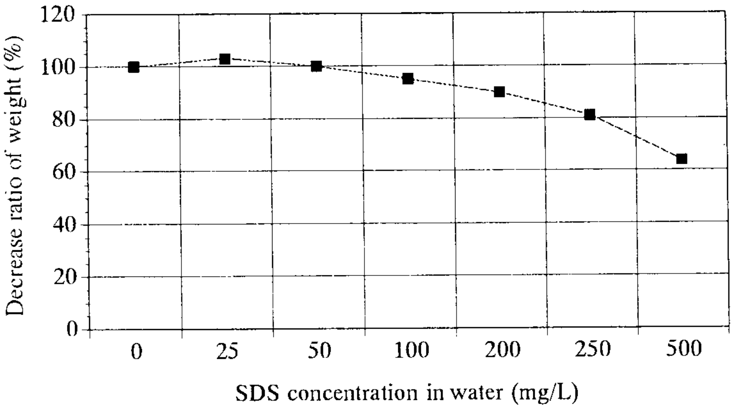

Figure 1, Relationship between the SDS concentration in water and the percentage weight of whole plants in control at 28 days from the beginning of the experiments.

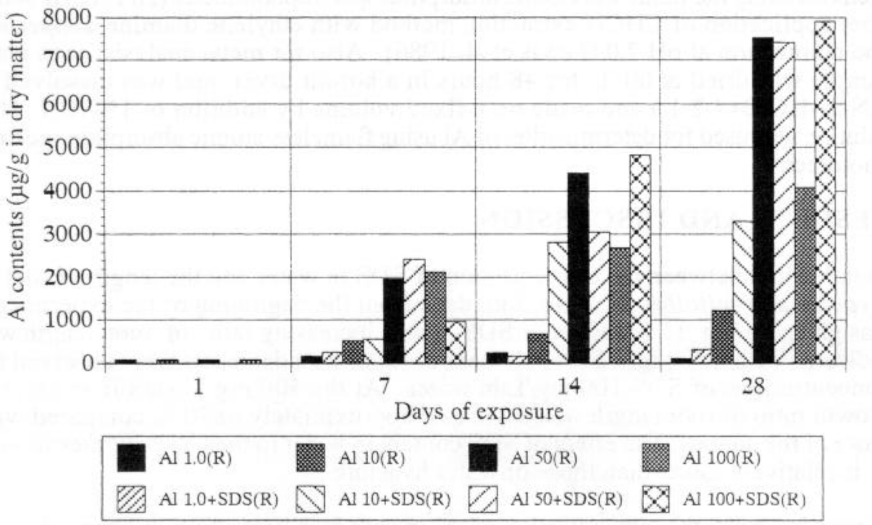

Figure 2. Al contents in roots(R) of plants exposed to water containing Al with or without SDS 100 mg/L.

The concentration factors in both of roots and tops of plant, *Cyperus alteriniforius* L. with exposure to Al containing water with or without SDS 100 mg/L for 28 days was shown in Table 1. The concentration factor of root in metal with SDS application group is significant higher than those in metal alone group ($p< 0.05$). However, that phenomenon in stem of plant was not recognized except for slightly ncreasing concentration. Also, the concentration factor for aluminum was lower compared with cadmium and lead by water hyacinth (Muramoto et al. 1980, 1989.

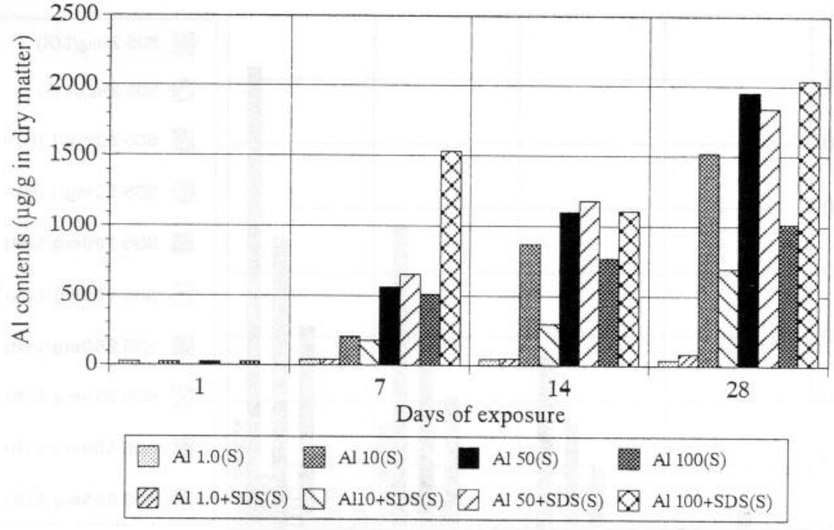

Figure 3. AI contents in stems(S) of plants exposed to water containing Al with or without SDS 100 mg/L.

Table 1. Concentration factors of *Cyperus alterinifolius* L. when exposed to water containing Al with or without SDS 100 mg/L.

Treatment	Al alone		Al + SDS	
	root	stem	root	stem
Al 1 mg/L	2.99×10^{3}	3.32×10^{2}	1.93×10^{3}	4.78×10^{2}
10	7.19×10^{2}	6.03×10^{2}	1.78×10^{3}	4.15×10^{2}
50	8.91×10^{2}	2.32×10^{2}	8.79×10^{2}	2.19×10^{2}
100	2.41×10	1.20×10^{2}	4.69×10^{2}	1.21×10^{2}

It was indicated that the accumulation of aluminum is lower accumulation metal in the case of metal alone exposure to plant and aquatic animals (Foy et al. 1978; Muramoto 1981).

Changes in the concentration of sodium dodecyl sulfate in tops and roots of *Cyperus alterinifolius* L. exposed to SDS containing water during 28 days is shown

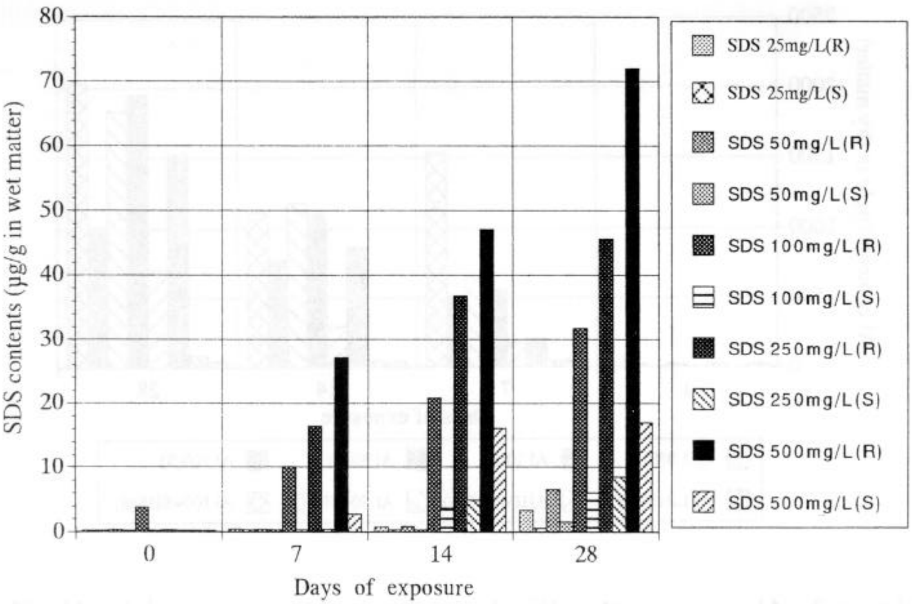

Figure 4. SDS contents in roots and stems of plant exposed to water containing SDS.

in Fig. 3. The SDS concentrations in both roots and tops were increased with increasing concentrations of SDS, and with passage of time, except for the 25 mg/L SDS group. The uptake of SDS by plants was higher in root than those in tops by about 4 - 12 times.

These results may provide information on the surfactant, sodium dodecyl sulfate, and adult plants. This surfactant induces plant growth at a concentration of 50 - 75 mg/L. The nature inhibition may be related to the root. A measure of the rate of metabolism in the plant would indicate the sensitivity of this plant species as a biological indicator for environmental monitoring. The widespread use of surfactant's results in their introduction into the environment where they can produce undesired effects. Thus it is important to perform studies to evaluate the importance of surfactants in the aquatic and soil environment to provide information on their fate.

Figure 4 shows the uptake of SDS in roots and tops of *Cyperus alterinifolius* L. exposed to Al containing water with or without SDS 100 mg/L. The uptake of SDS in both in root and tops of plant exposed to Al 50 mg/L with SDS 100 mg/L containing water was higher than those of SDS alone group. Wiliest, Table 2 indicate the significant deference between the roots and tops of the plant. The uptake of SDS in plants was recognized significant higher of root than those of tops in SDS alone treatment group ($p < 0.05$). However, no significant difference was recognized in Al plus SDS group. It was indicated that the translocation of SDS from the root tissue to the top of plant, and was encouraged with the consistence aluminum. However, the SDS uptake by plant exposure to high concentration of alumi-

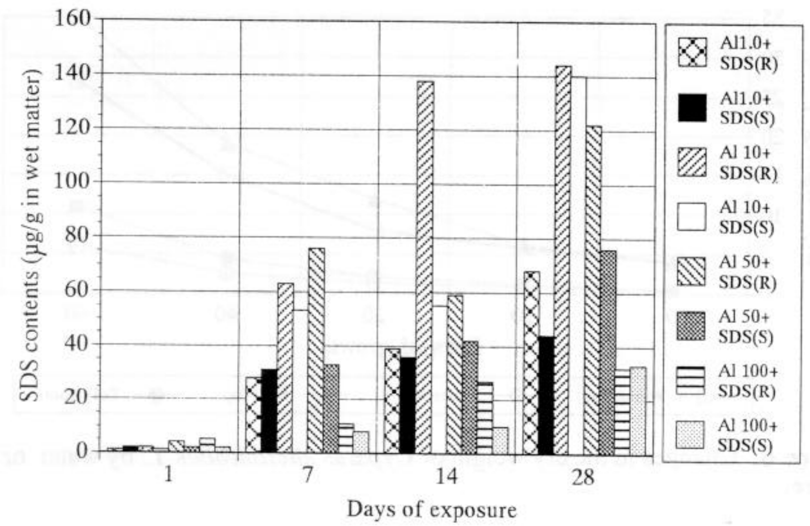

Figure 5. SDS contents in roots and stems of plants exposed to water containing Al with or without SDS 100 mg/L.

Table 2. Significant differences by student]s t-test in roots and stems treated with Al alone or Al with SDS 100 mg/L.

Part of Plants	Treatment	Significant differences (t-values)	Number of samples
Roots	[Al - (Al+SDS)]	3.030 *	4
Stem	[Al - (Al+SDS)]	1.219	4

* : $p < 0.1$

num with or without SDS 100 mg/L was decreased compared with those of plant exposure to the low concentration. It was considered that root of plants exposed to high concentration of aluminum induced by aluminum toxicity. The damageds of the surface of root tissue by Al with 100 mg/L SDS was recognized. The increasing of SDS uptake was indicated within 50 mg/L in water but decreasing tendency was observed for the concentration of 100 mg/L SDS in water.These data indicate the absence of Al accumulation in the root system, which may be due to the absence of binding of Al-SDS complexes to cell wall changes. Also the Al content of the root seems to be insignificant if compared to the Al transport to tops. At higher Al concentrations, there is no visible influence of SDS on Al uptake at the Al concentration is about 15 times the SDS concentration applied after harvest of *Cyperus Alteriniforius* L. absorbed nutrients and surfactant, the plants were used for paper works and pulp manufacture as source for paper. It is supposed that the effective use for recycle of plants in the natural environment.

The changes in the day weight of *Cyperus alteriniforius* L. in water and soil

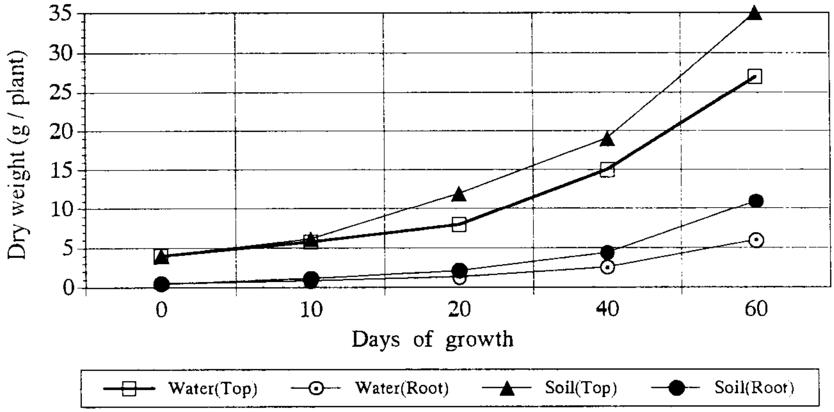

Figure 6. Changes in the dry weight of *Cyperus alterinifolius* L. by water or soil culture.

culture in other examination were shown in Fig. 6. The amount of dry weight for optimum harvest was 7,000 kg/ha in water culture from this results. The amount of uptake of Aluminum and SDS by *Cyperus alternifolius* L. from the polluted water in natural field were estimated using the dry weight of optimum yield culti vated in natural water fields as maintaining the nutrient good condition by adding fertilizers were as follows: 220 kg/ha in 1.0 mg/L Al containing water, 3200 kg/ha in 10 mg/L Al, 1660 kg/ha in 50 mg/L Al , and 3700 kg/ha in 100 mg/L Al, respectively. Also, the amount of uptake of anionic surfactants, SDS by *Cyperus alterinifolius* L. were as follows : 5.5 kg/ha in 25 mg/L SDS, 11.5 kg/ha in 50 mg/L SDS, 168 kg/ha in 100 mg/L SDS , 242 kg/ha in 250 mg/L SDS, and 196 kg/ ha in 500 mg/L SDS containing water, respectively.

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